Physio-biochemical and nutrient constituents of peanut plants under bentazone herbicide for broad-leaved weed control and water regimes in dry land areas

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Abstract: The abundance of broad-leaved weeds in peanut fields represents the handicap in weed management programs, since limited specific herbicides can be recommended to control them. Moreover, the physio-biochemical constituents and nutritional status in peanut plants as affected by available herbicides, i.e., bentazone under water stress conditions are not well known. Therefore, field trials were conducted during the growing seasons in 2016 and 2017 to investigate the interactional impact of irrigation levels (I_{50}, I_{75} and I_{100}, representing irrigation by 50%, 75% and 100% of crop evapotranspiration, respectively) and weed control practices (bentazone, bentazone+hoeing once, hoeing twice and weedy check as control) on dominant broad-leaved weeds as well as peanut physiological and agronomic traits. Result indicated that the efficiency of weed control for each weeded treatment under I_{50} significantly equaled with its counterpart under I_{75} or I_{100}. Bentazone+hoeing once diminished weed biomass by 89.3% and enhanced chlorophyll content of peanut plants by 51.2%. Bentazone relatively caused a reduction in carotenoides. Hoeing twice and bentazone+hoeing once under I_{100} in both growing seasons as well as hoeing twice under I_{75} in 2017 were the superior combinations for boosting pod yield of peanut plants. Treatment of bentazone+hoeing once and I_{75} recorded the lowest reduction in N utilization percentage and the highest increase in potassium utilization percentage of peanut plants. Eliminating weeds enhanced water use efficiency by 37.8%, 49.6% and 34.7% under I_{50}, I_{75} and I_{100}, respectively. In conclusion, peanut seems to be tolerant to bentazone at moderate water supply, thus it can be safely used in controlling the associated broad-leaved weeds.

Keywords: biochemical traits; drought; nutritional status; peanut productivity; weed growth

1 Introduction

Peanut or groundnut (*Arachis hypogaea* L.) is a legume and oilseed crop and its edible seeds are directly eaten or used for oil extraction. Seeds contain about 50% oil, 20% carbohydrates and 25% protein (Weiss, 1983), thus several usages and manufacturing purposes are achievable.

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As a result of infrequent water supply in dry land areas, farmers are forced to reduce the amount of water required for the crop irrigation, but this is accompanied by a lack of productivity and quality. Therefore, removing sources of water loss is of great importance. Water deficit is the prime ecological restriction to hinder the productivity of peanut (Awal and Ikeda, 2002). Saudy and El–Metwally (2019) recorded noticeable reductions in peanut biomass yield and seed nutrient constituents due to the low water supply.

Undoubtedly, weeds cause enormous issues in agricultural production since they interfere (via competition and allelopathic effects) with crop plants, which threaten food security, besides water wastage. Globally, weeds are potentially accountable for 34% of crop loss directly competing for water, causing less water available for crop plants (Oerke, 2006). Many weeds are known to be water wasters (Patterson, 1995). Weeds caused about 39% reduction in peanut yield and decreased harvesting efficiency under weedy condition (Jhala et al., 2005; Clewis et al., 2007). While, the plant height and dry matter production of peanut were enhanced with weed free environment (Singh and Giri, 2001). Both water requirements of the vegetation growth and moisture–competitive relations between the cultivated crops and weed plants are disturbed as a result of weed transpiration requirements (Pivec and Brant, 2009). Accordingly, combating weed in peanut field is essential for water saving and crop potentiality.

The use of herbicides, even in tolerant species, can create stressful circumstance expressed in the occurrence of phytotoxicity, affecting plant growth and productivity. The negative impact of such abiotic pressure is often interposed by the oxidative damage due to production of reactive oxygen species (ROS), such as superoxide ($O_2^{\bullet-}$), hydroxyl free radical ($^{\bullet}OH$), singlet oxygen ($^1O_2$) and hydrogen peroxide (H_2O_2) (Gill and Tuteja, 2010). Of course, it gets worse with scarce water, since drought is another abiotic stress.

Controlling broad-leaved weeds in broad-leaved crops, i.e., peanut using specific herbicides, is strenuous. Thus, the farmers apply hand weeding although it requires more labor intensive than herbicides. In this situation, the accessibility to an appropriate herbicide is considered a crucial action. Bentazone is a selective post emergence herbicide for controlling several broad–leaf weeds. In soybean, interestingly, seven ascorbate peroxidases (APXs), which have key roles to convert H_2O_2 into water in diversified subcellular locations, decreased in bentazone treatment (Zhu, 2009). However, the information about its impacts on peanut is not sufficiently available particularly under water deficit conditions. Hence, for keeping the weed density and biomass below the economic threshold level with healthy crop status particularly under low water supply, the efficacy of bentazone herbicide and susceptibility of peanut plants were evaluated under various water regimes.

2 Material and methods

2.1 Site characterization

During the growing seasons of 2016 and 2017, peanut plants were grown in field experiment at the Experimental Farm, El Nubaria District, Egypt (30°31′N, 30°18′E; 21 m a.s.l.). According to the method described by Jackson (1973), soil of the study area was sandy loam in texture with pH 7.72, EC 0.23 dS/m and organic matter 0.14%. Based on US Soil Taxonomy, the soil belongs to the order Aridisoil and suborder Durids. Physical properties and water status of the experimental soil are shown in Table 1. During growth stages, the means of the ambient air temperature, relative humidity and solar radiation were 27.5°C, 42.8% and 27.6 MJ/(m^2·d), respectively. Wheat was the preceding cultivated crop in both seasons.

2.2 Experimental treatments and procedures

For estimating the performance of peanut plants and the accompanied broad-leaved weeds to the integrated packages of irrigation levels and weed control patterns, three irrigation levels (irrigation by 50%, 75% and 100% of crop evapotranspiration, symbolized as I_{50}, I_{75} and I_{100},

respectively) and four weed control treatments (bentazone, bentazone+hoeing once, hoeing twice and weedy check) were applied. Plants were irrigated through trickle irrigation system that had emitters spaced 30.0 cm apart with discharge of 2.0 L/h.

Table 1 Physical traits and water status of the soil at the El Nubaria District

Depth (cm)	Particle size (%)			Texture	BD (g/cm^2)	Percentage of water contents on weight basis (%)		
	Sand	Silt	Clay			FC	PWP	AW
0–15	89.0	6.7	4.3	Sandy	1.54	12	4.1	7.9
15–30	88.4	7.4	4.2	Sandy	1.57	12	4.1	7.9
30–45	88.1	7.9	4.0	Sandy	1.60	12	4.1	7.9

Note: BD, bulk density; FC, field capacity; PWP, permanent wilting point; AW, available water.

Using FAO Penman–Monteith equation (Allen et al., 1998) for the growing season of peanut, irrigation water requirement was calculated by estimating daily reference evapotranspiration (ET_0) developed by FAO (Eq. 1). Thereafter, crop evapotranspiration was calculated using Equation 2 as described by Doorenbos et al. (1977). Accordingly, the quantity of irrigation water was computed as elucidated by Keller and Bliesner (1990), which is shown in Equation 3.

$$\mathrm{ET}_0 = \frac{0.408\,\Delta\left(R_\mathrm{n} - G\right) + \gamma \times \dfrac{900}{T + 273} u_2 \left(e_\mathrm{s} - e_\mathrm{a}\right)}{\Delta + \gamma(1 + 0.34u_2)}, \tag{1}$$

where ET_0 is the reference evapotranspiration (mm/d); R_n is the net radiation at the crop surface (MJ/(m^2·d)); G is the soil heat flux density (MJ/(m^2·d)); T is the mean daily air temperature at 2 m height (°C); u_2 is the wind speed at 2 m height (m/s); e_s is the saturation vapour pressure (kPa); e_a is the actual vapour pressure (kPa); e_s–e_a is the saturation vapor pressure deficit (kPa); Δ is the slope of vapor pressure curve (kPa/°C); and γ is the psychrometric constant (kPa/°C).

$$\mathrm{ET_c} = \mathrm{ET_0} \times \mathrm{K_c}, \tag{2}$$

where ET_c is the crop evapotranspiration (mm/d); ET_0 is the reference evapotranspiration (mm/d); and K_c is the crop coefficient (0.6–1.2).

$$\mathrm{IR} = \mathrm{ET_c} \times \mathrm{LR} \times 10 \,/\, E_\mathrm{a}, \tag{3}$$

where IR is the irrigation requirement (m^3/hm^2); LR is the leaching requirement (%); and E_a is the water application efficiency.

Bentazone (3-(1-methylethyl)-(1H)-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide), at a rate of 1.25 L/hm^2 was sprayed as post emergence herbicide 20 days after sowing (DAS). A knapsack sprayer had one nozzle with 476 L water/hm^2 as a solvent/carrier was used. Hoeing twice treatment was applied at 21 and 42 DAS. Also, hoeing once followed the herbicide was done at 42 DAS.

The net area of the experimental unit was 10.5 m^2; involving five ridges, 3.5 m length and 0.6 m width. Single super–phosphate (15.5% P_2O_5, 350.0 kg/hm^2), was incorporated during land preparation. On 1 and 5 May in 2016 and 2017, respectively, peanut Giza 6 cultivar seeds (3–4 seeds per hill) were inoculated with the specific *Rhizobium* strain and immediately sown, 0.25 m apart on both sides of the ridge. At 21 DAS, plants were thinned to one plant per hill as well as 150.0 kg/hm^2 ammonium nitrate (33.5% N) was added. Moreover, plants were fertilized by 150.0 kg/hm^2 of potassium sulphate (48.0% K_2O) at 35 DAS.

2.3 Measurements

2.3.1 Weed biomass

The dominant floras at the experimental site were broad-leaved weeds including common purslane (*Portulaca oleraceae*), Nalta jute (*Corchorus olitorius*) and Venice mallow (*Hibiscus trionum*). Weeds were hand pulled from each experimental plot at 90 DAS, oven dried and weight was registered per square meter.

2.3.2 Physio-biochemical traits of peanut

A sample of green leaves was taken at 75 DAS to estimate total leaf pigments (chlorophylls and carotenoids) as described by Witham et al. (1971). At harvest (114 and 119 DAS in 2016 and 2017, respectively), plants of the central two ridges were collected to estimate pods number and weight/plant, seed index and pod yield. Furthermore, according to AOAC (2005), seed samples were taken to extract and measure total carbohydrates, soluble sugars and oil content.

2.3.3 Nutrient content of peanut

According to Cottenie et al. (1982), nutrients, i.e. nitrogen (N), phosphrous (P) and potassium (K) contents of seeds and shoots were estimated. Moreover, nutrient utilization (NU) percentage of each N, P and K were computed as an average of the two seasons using Equation 4.

$$\mathrm{NU} = \frac{\text{Element content in seed}}{\text{Element content in total biomass}\left(\text{seed} + \text{shoot}\right)} \times 100\% . \tag{4}$$

2.3.4 Water use efficiency of peanut

Water use efficiency (WUE, kg/m^3) for peanut was estimated using Equation 5 relying on the obtained pod yield (kg/hm^2) and the amounts of irrigation water (1932–1990, 2898–2985 and 3864–3980 m^3/hm^2 for I_{50}, I_{75} and I_{100} in 2016 and 2017, respectively).

$$\mathrm{WUE} = \frac{\text{Pod yield}}{\text{Irrigation water amount}} . \tag{5}$$

2.4 Data analyses

The experimental design used was a strip–plot with three replicates. Analysis of variance (ANOVA) was conducted according to Casella (2008), using MSTAT–C software program (MSTATC, Michigan State Univ., 1992). For discriminating the treatment means, each of the Duncan's multiple range test (alphabetical letters) and the least significant difference test at $P<0.05$ ($LSD_{0.05}$) were used.

3 Results

3.1 Weed biomass

Dry weight of broad-leaved weeds was significantly affected by irrigation level×weed control in 2016 and 2017 (Fig. 1). In weedy check plots, the increase in dry weight was obtained with increasing irrigation level from I_{50} to I_{100}. Under each irrigation level, hoeing twice was the potent practice for controlling weeds surpassing the herbicidal treatments. With I_{50}, the efficiency of weed control for each weeded treatment significantly equaled with its counterpart under I_{75} or I_{100}.

3.2 Physio-biochemical traits of peanut

3.2.1 Leaf pigments

The maximum chlorophyll content of peanut leaves was recorded with hoeing twice×I_{100} and equaled with bentazone+hoeing once×I_{100} in both seasons (Table 2). Also, hoeing twice×I_{100} and hoeing twice×I_{75} (in 2016 and 2017) as well as bentazone+hoeing once×I_{100} in 2017 showed distinctive effects on carotenoides. Under moderate water stress (I_{75}), bentazone+hoeing once treatment was as similar as hoeing twice for chlorophyll content in both seasons.

3.2.2 Total carbohydrates, soluble sugars and oil

ANOVA result in Table 2 showed that irrigating peanut plants with I_{100} or I_{75} and controlling weeds using hoeing twice had the highest carbohydrate content during the growing seasons in 2016 and 2017. Such effective practice was statistically confirmed with bentazone+hoeing once (in 2016 and 2017) and bentazone alone (in 2017) under I_{100}. However, only hoeing twice×I_{100} treatment was the remarkable interaction for enhancing sugar content. Moreover, hoeing twice, bentazone+hoeing once and bentazone under I_{100} as well as hoeing twice and bentazone+hoeing

once under I_{75} showed similar effect on oil percentage in 2016. Superiority in oil percentage appeared with the applications of hoeing twice and bentazone+hoeing once×I_{100} in 2017.

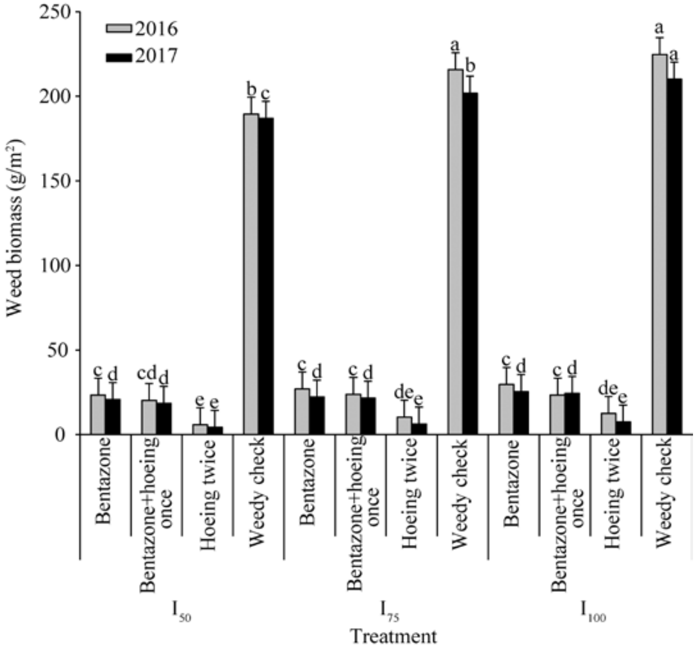

Fig. 1 Biomass of broad-leaved weeds associated with peanut plants as influenced by irrigation level×weed control. I_{50}, I_{75} and I_{100} are irrigations at 50%, 75% and 100% of crop evapotranspiration, respectively. $LSD_{0.05}$ was 9.6 in 2016 and 7.3 in 2017; different lowercase letters indicate significant differences among different treatments at $P<0.05$ level.

Table 2 Leaf pigments and seed biochemical components of peanut as influenced by irrigation level×weed control

Variable		Chlorophyll (mg/g)		Carotenoides (mg/g)		Total carbohydrates (mg/g)		Total soluble sugars (mg/g)		Oil (%)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
I_{50}	Bentazone	4.52^{e}	4.24^{f}	1.19^{ef}	1.40^{cd}	261.6^{g}	276.1^{e}	23.2^{f}	24.6^{h}	19.2^{e}	20.1^{de}
	Bentazone+hoeing once	4.88^{e}	4.82^{e}	1.40^{de}	1.62^{bc}	281.9^{ef}	314.7^{d}	24.4^{e}	25.3^{gh}	20.6^{d}	20.7^{cd}
	Hoeing twice	4.75^{e}	4.89^{e}	1.51^{de}	1.64^{bc}	311.6^{d}	323.0^{d}	26.3^{d}	25.5^{g}	20.7^{cd}	20.9^{cd}
	Weedy check	3.35^{g}	3.50^{g}	0.94^{ef}	1.15^{d}	222.9^{h}	231.0^{f}	19.9^{g}	21.1^{j}	17.8^{f}	18.1^{f}
I_{75}	Bentazone	5.52^{d}	5.70^{d}	1.41^{de}	1.44^{bcd}	320.1^{d}	330.4^{cd}	27.3^{cd}	28.4^{e}	21.3^{bcd}	21.1^{bcd}
	Bentazone+hoeing once	5.70^{cd}	5.78^{cd}	1.70^{cd}	1.79^{b}	346.6^{c}	360.7^{bc}	27.6^{c}	29.4^{d}	21.7^{abc}	21.2^{bcd}
	Hoeing twice	6.13^{bc}	6.24^{c}	2.12^{ab}	2.31^{a}	376.0^{ab}	379.0^{ab}	30.6^{b}	32.5^{c}	21.8^{ab}	21.5^{bc}
	Weedy check	3.69^{fg}	3.91^{fg}	1.22^{ef}	1.20^{d}	273.7^{fg}	269.2^{e}	22.4^{f}	23.2^{i}	18.4^{ef}	18.4^{f}
I_{100}	Bentazone	6.43^{b}	6.92^{b}	1.66^{cd}	1.69^{bcc}	361.9^{bc}	373.4^{ab}	28.3^{c}	30.2^{d}	21.6^{abcd}	21.5^{bc}
	Bentazone+hoeing once	7.33^{a}	7.50^{a}	1.87^{bc}	2.15^{a}	365.5^{ab}	390.4^{ab}	31.2^{b}	34.5^{b}	21.9^{ab}	22.2^{ab}
	Hoeing twice	7.55^{a}	7.88^{a}	2.41^{a}	2.48^{a}	379.9^{a}	406.4^{a}	34.7^{a}	35.6^{a}	22.4^{a}	22.9^{a}
	Weedy check	4.02^{f}	4.15^{f}	1.48^{de}	1.52^{bcd}	291.4^{e}	302.0^{de}	25.1^{e}	26.5^{f}	18.8^{ef}	19.1^{ef}
	$LSD_{0.05}$	0.44	0.50	0.30	0.35	16.3	35.3	1.1	0.8	1.0	1.1

Note: I_{50}, I_{75} and I_{100} are irrigations at 50%, 75% and 100% of crop evapotranspiration, respectively; different lowercase letters within the same column mean significant differences among different treatments at $P<0.05$ level. LSD means the least significant difference.

3.2.3 Agronomic traits

As shown in Table 3, all agronomic traits of peanut, i.e., pods number, pods weight, seed index and pod yield significantly responded to irrigation level×weed control. Generally, the most

effective combination for enhancing pods number and pods weight were hoeing twice×I_{100} or I_{75} in 2016 and 2017, and bentazone+hoeing once×I_{100} in 2017. The maximum values of seed index were recorded with hoeing twice and bentazone+hoeing once under I_{100} in 2016 as well as hoeing twice×I_{100} or I_{75} in 2017. Additionally, hoeing twice×I_{100} and bentazone+hoeing once×I_{100} in 2016 and 2017 as well as hoeing twice×I_{75} in 2017 were the superior combinations for boosting pod yield of peanut.

Table 3 Agronomic traits of peanut as influenced by irrigation level×weed control

Variable		Pod number/plant		Pod weight/plant (g)		Seed index (g)		Pod yield (t/hm^2)	
		2016	2017	2016	2017	2016	2017	2016	2017
I_{50}	Bentazone	34.4^{f}	31.8^{g}	32.4^{f}	31.3^{de}	60.2^{e}	62.7^{d}	4.34^{e}	4.36^{e}
	Bentazone+hoeing once	41.1^{e}	35.0^{gf}	43.3^{d}	27.4^{f}	65.6^{d}	68.1^{cd}	4.58^{e}	4.67^{e}
	Hoeing twice	45.1^{cd}	45.2^{cd}	51.4^{c}	34.0^{cd}	72.1^{c}	75.2^{b}	4.68^{de}	4.87^{de}
	Weedy check	24.1^{i}	25.0^{h}	20.4^{g}	18.0^{g}	35.0^{h}	38.6^{g}	3.17^{f}	3.63^{f}
I_{75}	Bentazone	43.3^{de}	41.2^{e}	48.8^{c}	32.8^{d}	65.9^{d}	73.2^{bc}	4.89^{de}	5.38^{cd}
	Bentazone+hoeing once	46.5^{c}	46.9^{bc}	54.6^{b}	34.1^{cd}	72.0^{c}	75.1^{b}	5.57^{bc}	5.43^{cd}
	Hoeing twice	53.3^{ab}	52.2^{a}	62.2^{a}	41.2^{b}	77.0^{b}	79.2^{ab}	5.80^{abc}	6.11^{ab}
	Weedy check	27.6^{h}	25.1^{h}	31.1^{f}	21.3^{g}	42.1^{g}	44.8^{f}	3.72^{f}	3.65^{f}
I_{100}	Bentazone	42.2^{e}	43.0^{de}	51.7^{c}	37.4^{c}	71.7^{c}	74.1^{bc}	5.25^{cd}	5.58^{bc}
	Bentazone+hoeing once	51.7^{b}	50.0^{ab}	50.8^{c}	43.0^{b}	78.2^{ab}	77.3^{b}	5.93^{ab}	6.43^{a}
	Hoeing twice	54.6^{a}	52.8^{a}	59.6^{a}	51.2^{a}	81.3^{a}	84.3^{a}	6.18^{a}	6.73^{a}
	Weedy check	30.8^{g}	31.0^{g}	40.0^{e}	27.8^{ef}	49.2^{f}	52.4^{e}	4.38^{e}	4.39^{e}
$LSD_{0.05}$		2.4	3.4	2.8	3.6	3.8	5.9	0.56	0.61

Note: I_{50}, I_{75} and I_{100} are irrigations at 50%, 75% and 100% of crop evapotranspiration, respectively; different lowercase letters within the same column mean significant differences among different treatments at P<0.05 level. LSD means the least significant difference.

3.2.4 N, P and K contents in seed and straw

Combination between irrigation level and weed control had significant effects on the contents of N, P and K in both seed and straw of peanut in 2016 and 2017, except for K in seed. The contents of N and P in seed showed the maximum increases with hoeing twice×I_{100} or bentazone+hoeing once×I_{100} in 2016 and 2017 as well as hoeing twice×I_{75} (for N) and bentazone alone×I_{100} (for P) in 2016 (Table 4). In straw, hoeing twice×I_{100} and bentazone+hoeing once×I_{100} had the highest values of N and K contents in 2016 and 2017. While, only hoeing twice×I_{100} was the superior treatment for the maximum P content in straw in 2016 and 2017. As shown in Figure 2, under each weed control treatment, the increase in water supply from I_{50} to I_{100} had significant increases in N utilization and decreases in P and K utilization. Compared with I_{100}, decreases in N utilization under I_{50} and I_{75} were 2.47% and 0.34% with bentazone, 4.45% and 0.01% with bentazone+hoeing once as well as 1.78% and 0.69% with hoeing twice, respectively. The increases were 5.64% and 4.28%, 5.90% and 1.67%, and 3.67% and 0.15% for P utilization, and they were 4.27% and 2.37%, 4.67% and 6.49%, and 6.03% and 2.90% for K utilization under I_{50} and I_{75}, respectively.

3.3 Water use efficiency (WUE) of peanut

Data in Figure 3 revealed that WUE values increased with the decrease in water supply. Thus, the maximum WUE occurred at I_{50}, especially in plots hoeing twice followed by bentazone+hoeing once. Over all seasons and weed control treatments, eliminating weeds increased WUE by 37.8%, 49.6% and 34.7% with I_{50}, I_{75} and I_{100}, respectively, compared with weedy check treatment.

Table 4 N, P and K contents in peanut seed and straw as influenced by irrigation level×weed control

Variable		Seed						Straw					
		N (%)		P (%)		K (%)		N (%)		P (%)		K (%)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
I_{50}	Bentazone	2.51^{fg}	2.51^{fg}	0.427^{e}	0.438^{fg}	2.15^{a}	2.30^{a}	1.80^{cde}	2.04^{de}	0.174^{f}	0.251^{efg}	1.61^{cd}	1.57^{cd}
	Bentazone+ hoeing once	2.58^{ef}	2.49^{fg}	0.447^{de}	0.466^{efg}	2.25^{a}	2.33^{a}	2.06^{bcd}	2.21^{cde}	0.232^{e}	0.272^{ef}	1.73^{bc}	1.81^{abc}
	Hoeing twice	2.75^{def}	2.75^{e}	0.473^{de}	0.512^{de}	2.28^{a}	2.40^{a}	2.19^{sc}	2.23^{cde}	0.263^{d}	0.338^{d}	1.76^{bc}	1.83^{abc}
	Weedy check	2.21^{g}	2.33^{g}	0.386^{e}	0.409^{g}	2.09^{a}	2.25^{a}	1.54^{e}	1.62^{f}	0.152^{f}	0.212^{g}	1.37^{d}	1.36^{d}
I_{75}	Bentazone	3.01^{cd}	3.15^{d}	0.524^{cd}	0.547^{cd}	2.27^{a}	2.42^{a}	2.19^{bc}	2.29^{cd}	0.269^{d}	0.278^{e}	1.70^{bc}	1.80^{abc}
	Bentazone+ hoeing once	2.94^{cde}	3.53^{c}	0.561^{bc}	0.573^{c}	2.35^{a}	2.47^{a}	2.40^{ab}	2.52^{bc}	0.323^{c}	0.376^{cd}	1.68^{bc}	1.90^{abc}
	Hoeing twice	3.45^{ab}	3.67^{bc}	0.571^{abc}	0.597^{abc}	2.43^{a}	2.48^{a}	2.73^{a}	2.85^{ab}	0.373^{b}	0.409^{bc}	1.93^{ab}	2.10^{ab}
	Weedy check	2.54^{fg}	2.70^{ef}	0.422^{e}	0.434^{fg}	2.22^{a}	2.33^{a}	1.72^{de}	1.81^{ef}	0.218^{e}	0.234^{fg}	1.58^{cd}	1.65^{cd}
I_{100}	Bentazone	3.12^{bc}	3.66^{bc}	0.596^{abc}	0.591^{bc}	2.33^{a}	2.43^{a}	2.41^{ab}	2.48^{bc}	0.327^{c}	0.356^{d}	1.84^{bc}	1.91^{abc}
	Bentazone+ hoeing once	3.56^{a}	3.78^{ab}	0.633^{ab}	0.635^{ab}	2.44^{a}	2.55^{a}	2.68^{a}	2.90^{ab}	0.375^{b}	0.441^{ab}	2.12^{a}	2.15^{a}
	Hoeing twice	3.73^{a}	3.92^{a}	0.651^{a}	0.655^{a}	2.42^{a}	2.56^{a}	2.78^{a}	3.12^{a}	0.410^{a}	0.464^{a}	2.19^{a}	2.16^{a}
	Weedy check	2.72^{def}	3.07^{d}	0.472^{de}	0.472^{ef}	2.39^{a}	2.30^{a}	1.91^{cde}	2.17^{cde}	0.269^{d}	0.277^{e}	1.68^{bc}	1.73^{bc}
$LSD_{0.05}$		0.33	0.20	0.079	0.056	ns	ns	0.41	0.39	0.031	0.039	0.25	0.33

Note: I_{50}, I_{75} and I_{100} are irrigations at 50%, 75% and 100% of crop evapotranspiration, respectively; different lowercase letters within the same column mean significant differences among different treatments at $P<0.05$ level. ns, no significance. LSD means the least significant difference.

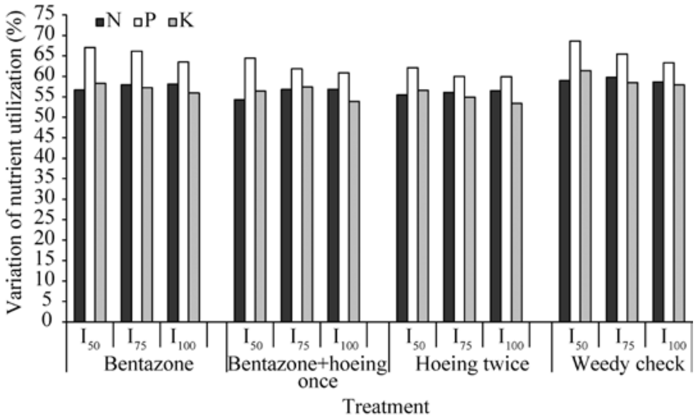

Fig. 2 Variation of nutrient utilization percentage of peanut as influenced by irrigation level×weed control. I_{50}, I_{75} and I_{100} are irrigations at 50%, 75% and 100% of crop evapotranspiration, respectively.

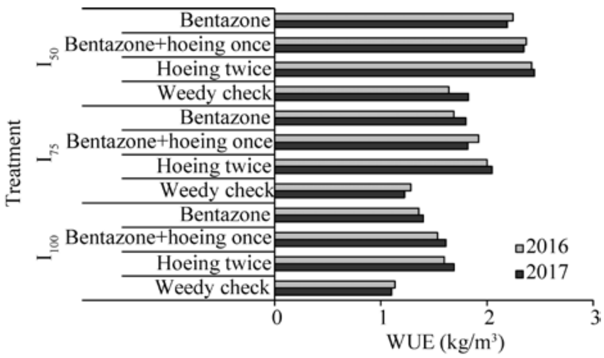

Fig. 3 Water use efficiency (WUE) of peanut as influenced by irrigation level×weed control. I_{50}, I_{75} and I_{100} are irrigations at 50%, 75% and 100% of crop evapotranspiration, respectively.

4 Discussion

The efficiency of each weed control treatment in combating weeds did not differ under various irrigation regimes, since the impacts of hoeing twice, bentazone+hoeing once and bentazone with I_{50} were similar under I_{75} or I_{100}, however, weed biomass values in weedy check were higher with high supply of water, i.e., I_{100} than other irrigation levels (Fig. 1). This indicates that under weedy conditions, water amount represents a limiting factor for the growth of weed flora of peanut. Herein, the reduction in weed biomass due to lowering water supply by 50% reached 13.4% (average of the two seasons) in weedy check plots. Nevertheless, by applying weed control treatments, the impact of irrigation water on broad-leaved weeds is neglected. Thus, lowering the amount of irrigation water by 25% can be implemented in weed control programs in peanut production.

Due to the important role of hoeing in controlling weeds by reducing their competitive ability, it helps the crop plants to exploit the ecological resources, i.e. water, nutrients, CO_2 and light. Therefore, hoeing twice, whether with low or adequate water supply, achieved excellent weed control (Fig. 1), and consequently well formation in leaf pigments (Table 2), accumulation in biochemical compounds (Table 3) as well as improvement agronomic traits (Table 4) and nutrient contents (Table 5) are fulfilled.

In spite of difficulty of using herbicides targeting broad-leaved weeds in a broad-leaved crop, bentazone plus hoeing once proved good potentiality against broad-leaved weeds in peanut, since such treatment equaled hoeing twice treatment with slight visual injuries on crop plants. In this respect, bentazone+hoeing once diminished weed biomass by 89.3% (Fig. 1) and improved chlorophyll content by 51.2% (Table 2), leveling with hoeing twice under I_{75}. Tolerance degrees to bentazone among different species are attributed to variations in uptake, translocation and metabolism. Herein, after foliar application, as post-emergence herbicide, bentazone is promptly absorbed by leaves (Vencill, 2002). Antagonistic impacts for plastoquinone action with inhibiting electron flow from photosystem II to photosystem I were obtained with herbicides treatment (Hess, 2000), leading to nutrient starvation. Moreover, oxidative stress resulted from reactive oxygen species (ROS) is commonly recognized as the most damaging stress induced by photosynthesis-inhibiting herbicides and the cause of cell death (Hess, 2000; Rutherford and Krieger–Liszkay, 2001). Rapid and prolonged production of ROS exceeds the quenching capacity of photo-protective components such as carotenoids, xanthophylls and tocopherol (Krasnovsky Jr, 1998; Trebst, 2003; Loll et al., 2005), causing severe oxidative damage of proteins, lipids and pigments, and eventually cell membrane destruction and plant death (Hess, 2000). Bentazone is a photosystem II-inhibiting herbicide that interferes with photosynthetic electron transport, thrilling oxidative stress (Zhu et al., 2009), and frustrating growth of susceptible plants as broad-leaved weeds. In bentazone-treated plants, triplet chlorophyll is the prime ROS resulted, which has relatively long lived and can react with O_2 forming toxic singlet oxygen (Rutherford and Krieger–Liszkay, 2001; Krieger–Liszkay, 2005), hence cell death is realized. Accordingly, in our study, treating broad-leaved weeds with bentazone led to a significant reduction in their biomass.

Concerning the crop, peanut plants also received drizzles of herbicide during post-emergence application. In this study, bentazone relatively caused reduction in leaf pigments especially carotenoides (Table 2), however, it seems that plants quickly recovered. The absorption and translocation of bentazone may be faster in sensitive plants than in tolerant ones (Bradshaw et al., 1992). However, Sterling and Balke (1989) clarified that tolerance to bentazone appears to be dramatically due to increased metabolic collapse. Transforming bentazone into glucosyl bentazon through cytochrome P450 might be the reason of its detoxification (Gronwald and Connelly, 1991; Burton and Maness, 1992). Plant tissue of soybean, the same family of peanut, is initially injured by bentazone, but then the plants swiftly improve to tolerate the herbicide because of induction of genes involved in glucoside conjugation of acylhydroxybentazon, which is not toxic to plants (Sterling and Balke, 1989). Recently, Zhu et al. (2009) found that soybean treated with bentazone showed symptoms of chlorosis and necrosis by 24 h after treatment but rapidly

retrieved their healthy growth by 48 h. Priya et al. (2013) clarified that herbicides plus hand weeding achieved acceptable level of weed control with boosting *Arachis hypogaea* pod yield.

Data depicted in Figure 2 indicated that mobility and accumulation of N, P and K nutrients differed due to irrigation level×weed control treatments. Herein, bentazone+hoeing once under moderate water supply (I_{75}) recorded the lowest reduction in N utilization percentage and the highest increase in K utilization percentage. This shows that such treatment achieved good balance in absorption of N and K, in addition to better mobilization from vegetative parts (leaves and stems) to seeds. Therefore, well practices applied, irrigation level×weed control, in peanut may affect nutrients distribution. Nutrients absorption and utilization of plants could be promoted through the optimization of management practices (Xue et al., 2010). Nzokou and Cregg (2010) reported that increasing water addition through irrigation is likely to leach mobile nutrients such as nitrates below the root zone. Moreover, the decrease in assimilation can be buffered by an increase in the plant abilities to provide N and other nutrients to various organs. In spite of obtaining higher values of WUE for each weed control treatments×I_{100} (Fig. 3), the increase percentages depicted proved the potency of hoeing twice or bentazoe+hoeing once with I_{75}. This means that such combinations achieved a good balance between the obtained marketable yield and the applied irrigation water, referring to the good utilization of each drop of water.

5 Conclusions

The current study showed that low susceptibility of peanut plants to bentazone herbicide enables the farmers to use it safely for controlling broad-leaved weeds. Under moderate water stress (I_{75}) that saves 25% of irrigation water, exploiting the benefits of hoeing and bentazone herbicide together is considered a quixotic integration for managing broad-leaved weeds in peanut fields to improve productivity and nutritional value of the crop.

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